# Ohio Agricultural Experiment Station.

# BULLETIN 97.

*WOOSTER, OHIO, DECEMBER, 1898.*

## SOME DISEASES OF WHEAT AND OATS.

THE SMUTS, RUST AND SCAB OF WHEAT.

FURTHER EXPERIMENTS IN THE PREVENTION OF OAT-SMUT.

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BULLETIN

OF THE

Ohio Agricultural Experiment Station.

NUMBER 97. DECEMBER, 1898.

# SOME DISEASES OF WHEAT AND OATS.

BY A. D. SELBY.

Although a staple product, like wheat, commonly secures its share of attention, increased demands for this cereal have recently given a heightened interest to all questions relating to its production. We have had, in the past few years the usual prevalence of diseases affecting wheat, and there have been made at this Station recent experiments in the treatment of smuts, especially. It therefore seems a suitable time to publish the results of this work, and of these studies, for the information of those interested in these questions.

For our region the smuts and rusts of wheat are the more prevalent and destructive fungous troubles; while scab, glume-spot and other parasitic diseases usually take a minor rank. At times, however, the scab has done in the past considerable injury.

Because of the similarity of treatment called for by the smuts of both wheat and oats it has been thought well to add the results of some experiments in the prevention of oat smut, following those reported in Bulletin 64 of this Station.

## THE WHEAT SMUTS.

Perhaps the most obvious and conspicuous diseases of wheat are the smuts; so called from the changes taking place in the grain bearing parts of the plant. The name "smut" means contaminated matter or dirty matter, which may have had a wider significance, at an earlier date, but now has come to be applied, in this connection, only to those affections of grain in which the diseased parts are converted into dark, powdery, dirty masses; in short, to those diseases produced by the smut

fungi, the Ustilagineæ. The cause of the smuts has its origin in the means by which these parasitic plants are propagated. The grain grower does not expect to produce a crop without placing the seed grain, properly covered, in suitable soil. No condition of weather or soil will bring forth a crop of grain unless this simple condition of seeding, practiced from the earliest times, has been complied with in the particular case. The statement just made may seem to many unnecessary; indeed the truth is axiomatic. Spontaneous generation is contrary to all the accumulated practical experience of the farmer and stock raiser. Something does not arise from nothing. The growth of every organism is, in every case, preceded by the growth of a like organism. These truths, so well recognized in the domain of the larger plants, with visible seeds, are equally true in the realm of the fungi. If the spores of the smuts are not sown, or present with seed grain, no smutted heads need be expected. The spores indeed correspond to the seeds of the grain crop, and unless in either case the spores of the smuts, or the seeds of the plants be sown, no smut fungus or grain crop need be expected. This fundamental truth is essential to a right comprehension of germ diseases of all sorts.

But with fungous diseases, as in the cultivation of larger plants of corn, of oats and of wheat, the varying combinations of soil and season will give different results. The yields indeed may vary from five to forty bushels per acre in case of wheat. But we accept without a question, that if no seed is sown there will be no crop and therefore, the above conditions cannot produce a variation in the amount of yield. Likewise do these same facts apply, in a degree, to the smuts, though the variation in the amount of smut, during different seasons, is much less than in the yield of wheat or in case of scab and rusts. The point to be made here is that the primal cause of these diseases is in the spores and not in the varying conditions under which the parasite may grow and cause damage.

We have two kinds of smut, the "loose smut" and the "stinking smut". There are these two kinds of disease because of the presence of two different kinds of parasites. The parasite of loose smut has its own sort of spores, which will produce only loose smut, and that only upon wheat. Loose smut spores beget only loose smut and conversely.

## LOOSE SMUT.

The smuts of the wheat affect the grain bearing parts or the grain itself. The loose smut converts the glumes, or chaff, including the contained parts,[1] into a mass of smut spores as shown in Fig. 1. The smut usually involves the entire head; though, occasionally, but the lower portion. Only the rachis of the part attacked remains in its original form, having the spores adhering to it. The most conspicuous stage of loose smut is at blossoming time of the wheat; subsequently, the spores

[1] A form of loose smut upon leaves of wheat has been reported from Egypt.

are carried away and only the blackened and bare tip of the stem may remain at harvest.

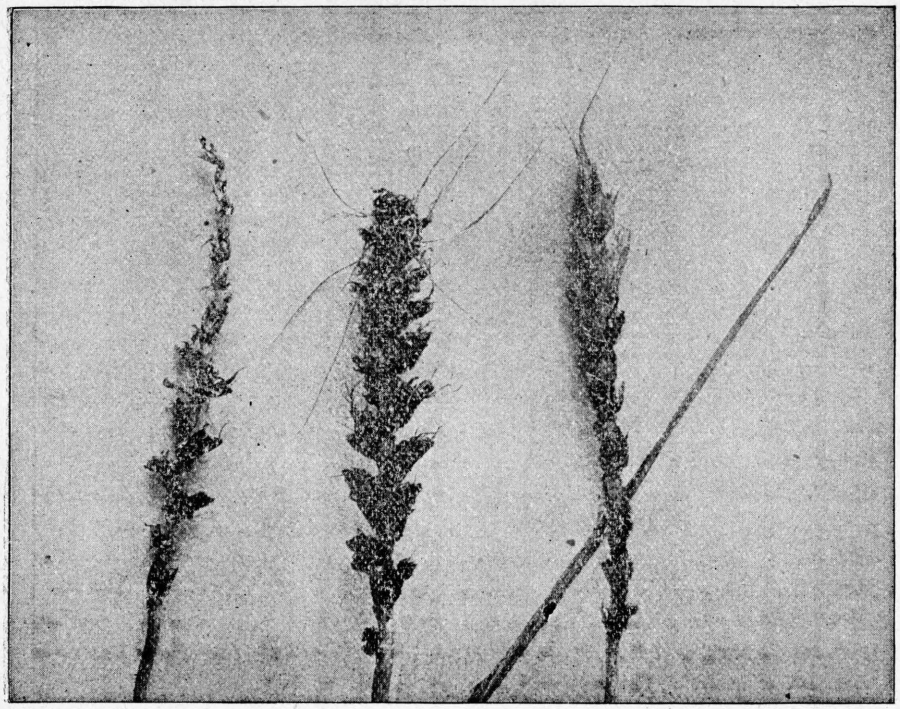


Fig. 1. Loose smut of wheat. At the left is shown a spike of smooth wheat, Poole, entirely destroyed by loose smut; at the right a spike of the same sort with upper portion remaining sound; in the middle a heavy spike of bearded sort, Square-head, entirely smutted and with heavier masses of spores. All from specimens collected at blooming of wheat.

(From a photograph by P. A. Hinman.)

The loose smut fungus is *Ustilago Tritici* Jensen, belonging to the same genus as the corn smut (*Ustilago Zeæ*) but is a distinct and separate species which affects only the wheat plant.

The development of this fungus in the wheat plant is similar to that of other loose smuts, except corn smut. The spores adhering to the seed grain germinate at the same time as the grain itself, and the germ-tube (promycelium) enters the young seedling. Once within the young wheat plant the fungus continues to grow, but without external manifestation. To the casual observer the head (spike) of grain is suddenly converted into smut, after the manner shown in the figure. Nevertheless, it is shown by microscopic study of the infected plants, that the fungus threads actually exist within the stem, consequently hibernating there, and the final production of spores has likewise been examined under the microscope. Experiments have, furthermore, shown that the promy-

celium of the smut fungus can only pierce, or enter the wheat plant when it is very young, through its first leaf sheath.

Another decided proof of infection by the seed grain is found in the prevention of smut development by the treatment of the seed to destroy the smut spores. While it is more difficult to attain the prevention of loose smut than of stinking smut, experiments reported on page 43 show that loose smut of wheat may be prevented by a suitable modification of the hot water treatment suggested by Swingle.[2] This involves some sacrifice of seed, about one-half the amount usually sown, yet the certainty of loose smut prevention seems assured.

### LOSSES FROM LOOSE SMUT — SUSCEPTIBILITY OF VARIETIES.

The losses from loose smut are rarely, though occasionally, large. In certain varieties, Hicks and Hickman, grown by this Station, eight per cent. of heads were affected by loose smut.[3] Seed of these varieties gave about three per cent. of smut in the untreated plots of '96. The actual average amount of loose smut in the wheat of the state is probably near one-third of one per cent. — one head in three hundred, though possibly higher at certain times and lower at others. Even this minute and almost invisible loss reaches a considerable amount when we compute it on the total amount of wheat production of 35,000,000 bushels in Ohio. The yearly loss from loose smut, at this rate, reaches 116,000 bushels, having a value of nearly $100,000. Though less than the losses from smut in oats, the amount is appreciable in fact.

The practical question of preventing this loss appears to depend upon variety selection and seed treatment. Such varieties as those alluded to and other susceptible sorts may not prove good ones by reason of this susceptibility. Seed treatment evidently does not require to be repeated each year; and clean, smut free seed, once secured, may usually be employed for several years without further treatment. Loose smut is less destructive, as well as more difficult to prevent, than stinking smut, which we will now consider.

### STINKING SMUT OF WHEAT.

Unlike loose smut, stinking smut affects chiefly, only the kernel of the grain, the glumes surrounding it remaining untouched. All the grains of the affected head are liable to be involved, though not always attacked, while the seed coat remains unbroken; once ruptured, the interior of the grains is found to be a dull, offensive-smelling mass of smut spores. This smell of the smut has given the name of "stinking" smut; and if the smut finds its way into the flour the latter becomes unfit for food.

[2] Yearbook, U. S. Dept. Agriculture, 1894, 417.

[3] Bulletin 42, Ohio Agricultural Experiment Station, p. 93 (1892).

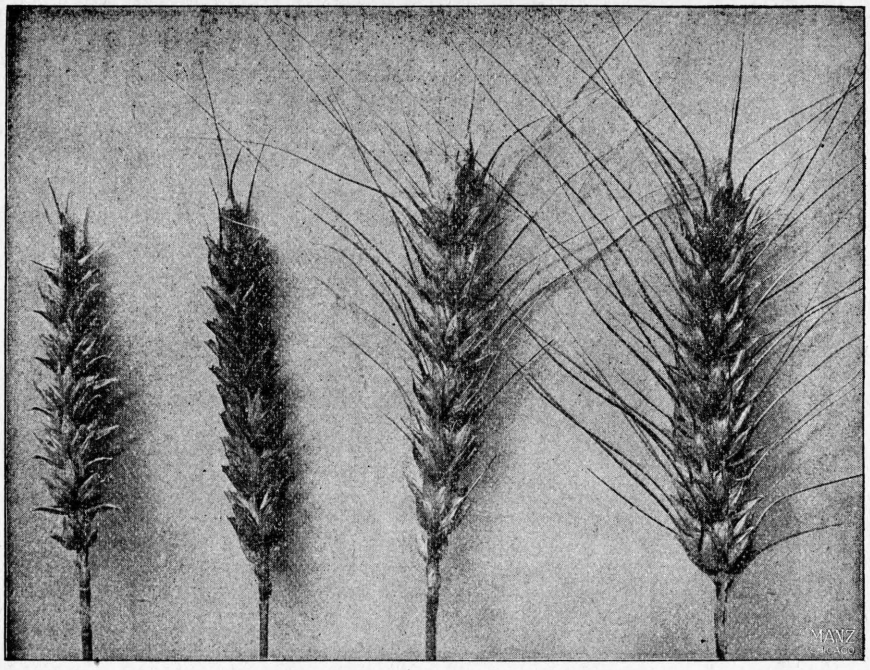


Fig. 2. Stinking smut of wheat. At the left is shown, first, a spike of Poole wheat affected with stinking smut, having paler spikelets spreading nearly at right angles to the stem and, second, a healthy spike of the same sort with the darker, erect and natural parts.

At the right a pair of spikes of Egyptian wheat, smutted and healthy, arranged in the same order. The wide-spreading beards, (which have disappeared below) offer, with the other parts, the same contrast as in the Poole sort. All the grains of the affected heads are smut balls as shown in Fig. 3.

(From a photograph by P. A. Hinman.)

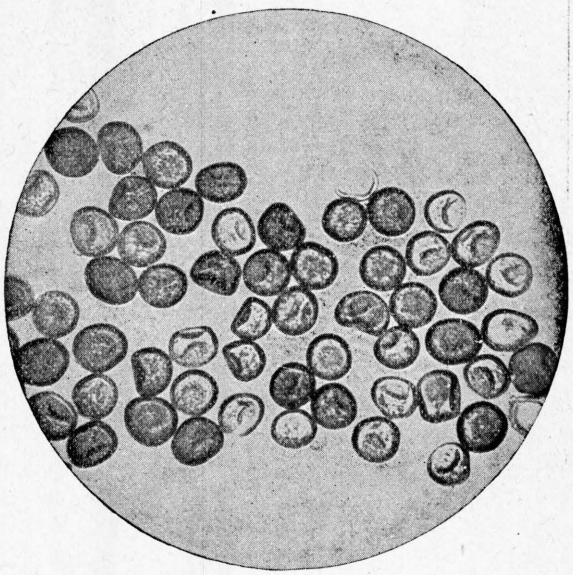
The parasitic plant, smut fungus, belongs, in this instance, to a different genus from that of loose smut; that is to *Tilletia*, not to *Ustilago*. There are two species of the stinking smut fungus reported, *Tilletia Triciti* and *Tilletia fœtens*, alike in all respects save that the former has sculptured or net-ridged, globose spores, while the spores of the latter are smooth and varying from globose to oval. Both are known to attack other species of Tricitum in Europe and elsewhere, but neither attacks other grains cultivated largely in Ohio. These smuts need not be feared upon rye, oats, barley, etc. The stinking smut problem is accordingly confined to the wheat crop.

Harwood[4] has pointed out that wheat attacked by *T. Tritici* has stalks as tall as healthy grain, while that attacked by *T. fœtens* has shorter stalks than unsmutted wheat; "high" smut and "low" smut, according to this author, are distinguished in southwestern Michigan.

[4] Bulletin 81, Michigan Experiment Station, p. 5, (1892).

During three seasons selections of "low" and "high" smut have been made at this Station by the writer; microscopic examinations have, as yet, failed to discover any constant difference in this regard. *Tilletia fœtens* appears to be the only one of the stinking smuts about Wooster. Stinking smut, irrespective of the particular one of the two species causing it, may be prevented by any treatment of the seed which will destroy adhering spores and still leave the seed grain uninjured. The bluestone, or blue vitriol, treatment (Kuhn's method) has been practiced for a long time, both by immersion of the seed in the copper sulfate solution and by sprinkling a pile of seed grain with it.[5] Quite generally this sulfate of copper treatment has been followed.

1



2

Fig 3. Stinking Smut, *Tilletia fœtens* (B. C.)

1. Shows entire grain smutted by this fungus; also sectional view disclosing the interior mass of smut spores. Both natural size. 2. Photo micrograph of the spores of the dark mass as they appear under the microscope magnified about 300 diameters.

It will be observed that the smut balls differ slightly in shape from the sound grains. Likewise that the spores of the smut have a form as constant and well defined as that of wheat kernels.

(1. From drawings by Mrs. Selby; 2. from photograph by Selby and Hinman.)

Recently the sprinkling method of seed treatment for smut has been revived. A comparison of the copper sulfate and hot water methods is given in the experimental portion of this bulletin. Should dry weather follow seeding with treated grain there is some danger of poor germination and, in this respect, there is slight choice of methods, that is, of

[5] See Bulletin Ohio Agricultural Experiment Station, Vol. IV, No. 4, p. 87, (1891).

either blue-stone or hot water, at 133° F., ten minutes' immersion. When favorably situated the advantage of cost is in favor of the hot water treatment and likewise on the score of handling poisonous material. In all treatment it is to be remembered that the treated seed easily becomes again infected if spread upon a surface carrying smut spores. Canvas dipped through boiling water, or a recently scalded floor that has been permitted to dry will serve admirably for drying the grain upon.

### LOSSES CAUSED BY STINKING SMUT.

The injury from stinking smut is extremely variable; partly for the reason that a considerable amount of the smut renders the grain containing it unmarketable. Only comparatively small percentages of the smut are likely to pass unnoticed in wheat offered for sale or used on the farm. Perhaps fifteen per cent. of stinking smut will place the grain among that used for chop and sold at one-third price; larger percentages below forty per cent. of smut certainly do. The loss from stinking smut will be all the way from nothing to seventy-five per cent. of the crop. In the instance cited below, where thirty-seven per cent. of the crop was smutted, the loss amounted to sixty per cent. of the crop, since probably about half the smut balls were separated from the grain in threshing. An annual loss of three-fourths to one per cent. seems not to be far from the truth. This means a yearly smut deficit of about $250,000 in Ohio. This loss is entirely preventable by the methods set forth in this bulletin.

### WILL SMUT FOLLOW A SMUTTED WHEAT CROP?

It has been stated that smutted seed is the usual source of smut infection. The chief reason for this is found in the proximity of smut spores carried upon the seed. It does not seem possible that land which has grown a smutted wheat crop will afford the conditions necessary to infect greatly the succeeding wheat crop, if volunteer wheat is not permitted to grow. A good opportunity to test this matter was available in the fall of 1895, through the courtesy of Mr. E. A. Manges, who lives upon a farm adjoining the Station grounds. A field in which thirty-seven per cent. of the heads were attacked by stinking smut in that year was again reseeded after fallow and cultivation, to destroy, as far as possible, the volunteer grain. By Mr. Manges' permission, plots of untreated grain from the crop of 1894 as well as 1895, and treated grain from both these years, were sown alongside clean seed purchased by him. The following are the results:

TABLE I.—WHEAT FOLLOWING A SMUTTED CROP.—VARIETY, POOLE.

| Plot. | Source of Seed. | Condition of Seed. | Smut Results. | | |
|---|---|---|---|---|---|
| | | | Total Counted. | Total Smutted. | Per cent. Smutted. |
| 1 | Manges—Seed of 1895 .... | Smutted 37%, Treated Hot Water * ..... | 2,165 | 5 | 0.23 |
| 2 | " " 1895 .... | Smutted 37%, Untreated ... | 2,837 | 550 | 19.3 |
| 3 | Manges—Seed of 1894 .... | Smutted, Hot Water ..... | 2,365 | 4 | 0.17 |
| 4 | " " 1894 .... | " Untreated.... .. | 1,743 | 191 | 10.96 |
| 5 | McSweeny—Seed of 1895.. | Clean, Untreated ..... | 1,474 | 2 | 0.13 |

*The hot water treatment was for 10 minutes at a temperature of 132-3° F., the grain having first been immersed in cold water and the smut-balls removed by skimming.

It will be seen that there were a few smutted heads in all the plots, probably explained by the volunteer wheat. See Table II, in which treated seed from the same vessel yielded no smut on fresh land. It would seem that these results offer no adequate basis for alteration of the judgment that the primal source of infection is through the seed sown.

OLD SEED NOT A PROBABLE MEANS OF AVOIDING SMUT.

The claim is sometimes made that smutted wheat, if kept for several years, may be sown without danger of smut in the crop produced. Experiments in this line do not seem to have been frequent; we find it recorded by Zopf,[6] upon the germinations of Liebenberg, that spores of *Tilletia Triciti* (Bjerk.), (*Tilletia Caries* Tul.) germinated after eight and one-half years. This for herbarium specimens of the smut. The remedy for smut in affected wheat is apparently to be sought in the treatment of the seed. For detail of treatment methods the reader is referred to pages 43-49.

## RUST OF WHEAT.

The rusts are a special class of parasites which contrast with the smuts in the parts affected and in the obvious localization of the fungus as well as in their form and manner of development. The spots attacked by rust may be readily seen while the sori of the fungus, first red and later dark brown, are seen upon the leaves, sheaths and stems. "Red" rust and "black" rust, commonly so-called, are but different stages in the development of the rust fungus in question; the lighter "red" spots, the earlier form upon the wheat, consist of one-celled, nearly spherical

[6] Die Pilze, p. 218.

*uredospores*, while the latter, more resistant development of the fungus, "black" rust, is the two-celled *teleutospore* stage. The latter may pass the winter upon the dead portions of the plant attacked, while the *uredospores* are commonly unable to survive; but in this connection it must not be forgotten that the wheat crop may become infected soon after sowing and the winter thus be passed in the wheat plant.[7] This statement applies to one of the species, *Puccinia rubigo vera*, only.

As recognized in the past, there are two species of rusts upon wheat. *Puccinia graminis* and *Puccinia rubigo vera*. Erriksson,[8] summarizing the results of the labors of himself and Hennings in Sweden, divides these two species into five, of which three *Puccinia graminis* Pers and *Puccinia glumarum* (Schw.) Er. and Hen., with its companion *Puccinia dispersa* Er. and Hen., formerly classed together as the second named species above, occur in that country upon wheat. We may fairly conclude that species discussion belongs elsewhere; yet striking features of these various rusts of cereals are the established facts of species limitations. Thus, while *Puccinia graminis* occurs upon twenty-three species of grasses in Sweden, only that form upon wheat communicates the rust to other wheat. The rust upon oats is often another species, *P. coronata* Corda (*P. Coronifera* Kleb.) although when *P. graminis* does attack oats we need have little fear of its having been communicated from the wheat, and conversely. In this connection the following extract from Erriksson[9] gives a better conception of the Swedish teachings at the present day: —

"To speak comprehensively, the investigation above outlined gives the following general conclusions:

*A. The outbreak of grain rust is due* (a) *in the first place to germs of disease in the host plant itself, which in certain cases are inherited from the parent plant through the seed, and in which they lead a latent symbiotic life as a mycoplasma and continue to do so afterwards for a long time in the resulting plant, and* (b) *in the second place, to external infection from the vicinity.*

*B. The intensity of grain rust is due,* (a) *in the first place to the degree in which the dominant outer circumstances (weather, soil, manuring, and so forth) are able to convert the inner germs of disease from the latent stage of a mycoplasma into a visible stage of mycelium, and* (b) *in the second place to the accession of infective material from without.*

"So far have we now gone in our knowledge of the nature of grain rust. Many things that before seemed incomprehensible have now a natural explanation, and our point of view has been very much changed. Especially have the experiments so far carried out provided a new method for explaining the varying susceptibility of different varieties of cereals, and have thus given a new point of departure for continued efforts for the mastery of the disease in the open field. We are warranted in suggesting that the predisposition of the Hosford wheat to yellow rust may be explained by assuming that between this variety of wheat and the yellow rust an extremely vital mycoplasma-symbiosis is to be found,

[7] Bolley, Bulletin Indiana Experiment Station, 26, and Carleton, Bulletin Kansas Experiment Station, 38, 11 (1893); 46, 1 (1894).

[8] Botanical Gazette, XXV, 26, (1898).

[9] Loc. cit., 37-38.

while on the contrary the Squarehead wheat is nearly exempt from the rust for the reason that no such symbiosis has arisen between this wheat and the fungus.

"With this fundamental view as a point of departure we have yet to ascertain to what degree we can by different manures, by different treatment of the soil, by different time of sowing, etc., influence the internal germs of disease in such a manner that the transformation from the latent mycoplasma stage to the sporiferous mycelium stage may be as much as possible delayed and prevented. We have further to make use of the knowledge gained in the selection and cultivation of varieties as little susceptible to the disease as possible. We have to find out to what degree by crossing we can combine a small susceptibility to rust with a strong resistance to cold, and finally whether certain regions may not tend to repress the development of the inner germ of the disease, and thus become regions for the production of certain kinds of cereals."

### PREVENTION OF GRAIN RUST.

Repeated experiments in the prevention of grain rusts have failed to show the efficiency of fungicidal treatment for this purpose.[10] Varietal susceptibility and its converse, non-susceptibility, with the correlated questions of ripening period, climate, etc., seem to promise in time, a partial solution of present difficulties with respect to grain rusts.

## WHEAT SCAB.

This disease, unlike those before considered, usually does not cause heavy loss. The interest attached to it, however, is quite marked. As harvest time approaches the scab fungus, by its attacks on the heads, causes dead sections, whose brown color is in striking contrast with the green, healthy glumes of the remaining portion. These dead portions may be situated at any portion of the spike, base, middle or apex. An examination of the base and margins of the dead glumes will show that a pinkish fungus has overspread them as well as the adjacent rachis. This is the scab fungus, which seems properly referable to *Fusarium roseum* Lk. See Figure 4. The peculiarity of the attacks of the fungus lies in their location; any section of the head, as has already been stated, is liable to the injuries of the scab fungus. At times when the disease prevails to a considerable extent the entire spikes are destroyed by the scab. And at all times pink incrustations of the fungus at the base of the dead glumes and covering the rachis may be relied upon for diagnosis.

It has been, for some time, a fruitful subject of discussion as to how this fungus passes the winter, since it is well known that the Fusarium is but a form genus, the ascigerous stage of which has been found among the genera of Hypocreaceæ. Saccardo[11] gives *Fusarium roseum* Link. as the conidial form of *Gibberella Saubinettii*, (Mont.) Sacc. Winter[12] refers

[10] Galloway, B. T., Journal of Mycology, VII, 195-226; Carleton, loc. cit. B. 38 and 46.

[11] Sylloge Fungorum, II, 554.

[12] Die Pilze, II, 102.

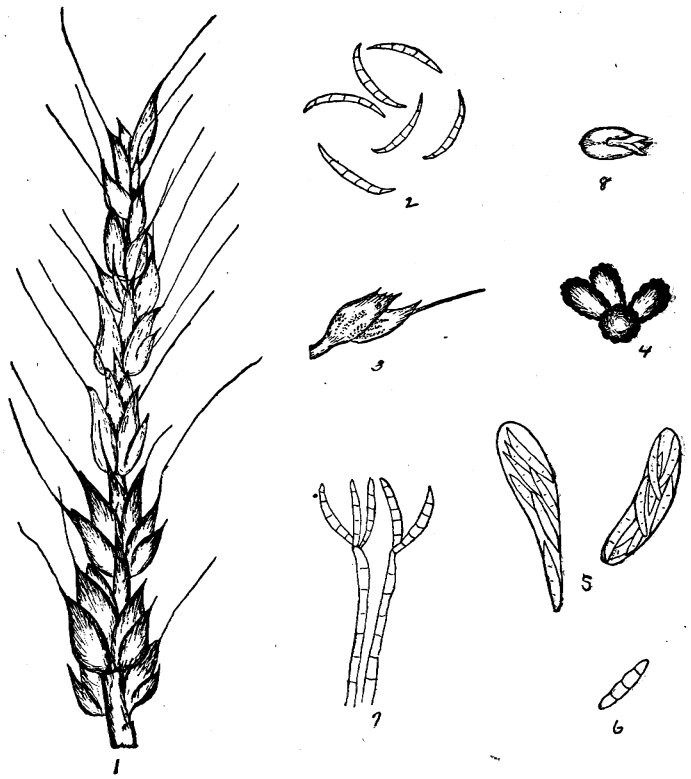



Fig. 4. Wheat scab, *Gibberella Sanbinettii* (Mont) Sacc.

At 1 is shown pen drawing of scabbed spike of wheat wherein the whole upper portion has been destroyed by the fungus which has formed pink incrustatations over the spikelets in many places; natural size. At 2 spores of the *Fusarium* forming the pink crusts which destroy the wheat, magnified about 200 diameters. (This is called *Fusarium* because of the spindle-form of the spores.) At 3 glumes covered by small spore cases (perithecia) of *Gibberella* which are found upon the pink crusts; 4 shows these perithecia more enlarged; each one contains many spore sacs, (*asci*) of forms like those shown at 5, much magnified; each ascus (plural *asci*) contains just 8 spores of the form shown at 6. At 7 is camera lucida picture of *Fusarium* grown in agar-agar culture by sowings of the spores of the *Gibberella* found on scabby wheat heads. At 8 is shown, natural size, a kernel of grain from a scabbed spike gathered in April. This has, in the projecting growths of fungus, an abundance of *Fusarium* spores like those at 2 and yet capable of germination.

(All from drawings by Mrs. Selby.)

the conidial stage of this Gibberella likewise to *Fusarium roseum* (in part). The studies of the writer have confirmed this view. Considerable time during 1892-3 was devoted to the study of this fungus in the laboratories of the Ohio State University, supplemented by frequent field excursions. In a wheat field situated in low ground where the grain had been badly affected by scab the Gibberella was found almost uniformly situated upon

the sporodochia of the Fusarium. Agar cultures of the spores of this Gibberella gave a uniform growth of Fusarium. Unfortunately the efforts to inoculate this fusarium in the field were without result. While not fully proven, it appears that the *Gibberella Saubinettii* must be an ascigerous condition of the scab fungus. The Gibberella is found upon fallen glumes, straw, corn stalks, stubble, etc., in the affected fields. It is well known that the spore cases (perithecia) are able to resist the ordinary weather conditions of the winter and thus to assure the wintering over of the fungus. In addition to this the badly affected grains of wheat are able to carry the fungus over in the fusarium stage. Such kernels, collected in April, 1895, were found incrusted with the fungus and furnished fusarium conidia capable of germination. A further curious fact was observed, namely: that the asci of the Gibberella disappear as the winter passes. In material gathered after October, very few asci remained, the spores being more or less massed together in the perithecia.

### LOSSES CAUSED BY SCAB.

As already stated, the losses from scab are usually inconsiderable, varying, however, with different varieties and especially with abundance of rainfall, at or near the time of heading out. Rudy wheat on the University Farm, Columbus, in 1893, had five to six per cent. of scabby heads, while larger losses have been reported.[13] Under conditions favorable to the fungus, losses of ten per cent., or more, are not unusual. In ordinary seasons, with the larger proportion of varieties grown in Ohio, the amount varies from nothing to one per cent. Arthur[14] has pointed out the susceptibility of certain French varieties to scab, and in general the greater prevalence of the disease upon those sorts which are late to mature.

### PREVENTION OF SCAB.

The remedies for this trouble must be, in the present state of our knowledge, almost entirely palliative or preventive. The rejection of susceptible varieties suggests itself, at once, as a means of reducing the proportions of scab. Where wheat is to follow a scabby crop burning the stubble over should prove effective in destroying both fallen heads and affected straw and stubble. It is not clear that the infection passes from corn stubble or corn stalks to wheat.

### GLUME SPOT.

The glumes of certain varieties, grown by the Experiment Station, are frequently spotted by a pycnidial fungus. These dark spots are very conspicuous upon Velvet Chaff, the sort used as a standard in variety comparisons. Other varieties are more or less marked in the same man-

[13] Weed, Society Promotion of Agricultural Science, 1888.
[14] Bulletin Indiana Agricultural Experiment Station.

ner. The fungus, in this case, appears to be one of the form genera and has been referred to *Septoria*.

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## EXPERIMENTS IN THE PREVENTION OF GRAIN SMUTS AND THE TREATMENT OF UNSMUTTED WHEAT SEED.

By J. Fremont Hickman and A. D. Selby.

Beginning in 1895 the writers have conducted, for three years, experiments to test the value of various methods of treatment for smuts and to ascertain, if possible, the effect of seed treatment upon yield of wheat when no smut was present in the seed. The results of these tests are set forth in the following pages and do not seem to require extensive comment.

### PREVENTION OF LOOSE SMUT OF WHEAT.

Swingle has suggested that the modified hot water treatment may be effective in the prevention of loose smut.[15] It has been noted that treatment of seed which successfully prevents stinking smut on wheat is ineffectual against loose smut. He recommends that the grain be soaked four hours in cold water, then set aside four hours more in wet sacks and finally treated by immersion in hot water at 132° or 133° F. for five minutes. Further, that by the above treatment the seed would suffer injury and one-half more seed must be sown per acre to compensate for that injury. Our experiments support the correctness of this recommendation. The experiments are given in Tables II and III, and appear below.

[15] Yearbook, U. S. Dept. of Agriculture, 1895, 417.

TABLE II.—TREATMENT FOR PREVENTION OF LOOSE SMUT OF WHEAT, 1895–6.

| Plot. | Variety. | Source and condition of seed. | Treatment. | Per cent. smutted. | Yield per acre. |
|---|---|---|---|---|---|
| | | | | | *Bush.* |
| 1 | Hickman | Seed of smutted. | Untreated | 1. | 5.25 |
| 2 | " | | Hot water, 132–3°, 5 m. seed previously soaked 4 hrs. and stood in wet sacks 4 hrs | 0.0 | 3.5 |
| 3 | " | | Untreated | 1.12 | 3.5 |
| 4 | " | | Hot water, 131°, 10m. seed previously soaked 4 hrs. and stood 4 hrs | 0.0 | 3.5 |
| 5 | Hicks | | Untreated | 2.68 | 4. |
| 6 | " | | Hot water, 132°, 5m. seed previously soaked 4 hrs. and stood in wet sacks 4 hrs | 0.0 | 4.5 |
| 7 | " | | Untreated | 2.44 | 2.5 |
| 8 | " | | Hot water, 131°, 10m. seed previously soaked 4 hrs. and stood in wet sacks 4 hrs | 0.0 | 3. |
| 9 | " | | Untreated | 3.34 | 3.25 |
| 10 | " | | Hot water, 132–3°, 5m. soaked 2 hrs., stood in wet sacks 12 hrs., then soaked 2 hrs. more before treatment | 0.0 | 1.5 |
| 11 | " | | Untreated—2 east hoes only. Remainder of treated Valley | 3.53 | ..... |
| 12 | " | | Carbol-soap mixture, 1.5%, 30m | 2.41 | 3. |
| | Hickman—Average of untreated | | | 1.6 | 4.37 |
| | " " hot water treated | | | 0.0 | 3.50 |
| | Hicks—Average of untreated | | | 2.82 | 3.25 |
| | " " hot water treated | | | 0.0 | 3.75 |

All plots sown October 5 and 7, 1895. Treated seed sown in 50% greater quantity than untreated; latter at rate of 5 pecks per acre. Soil very dry and finely pulverized.

All grain at the Station was badly winter killed in 1895-6, and these treated plots, accordingly, gave very low yields. There was better growth of plants upon the untreated than upon the treated plots throughout the fall. The treatment on plots two and six is that referred to above. It alone was employed the following year, as shown in Table III.

The loss of grain by this method of treatment appears unavoidable in successful prevention of loose smut. The method is not especially difficult of application, and is readily available, and it would seem effective, for the prevention of loose smut. Stinking smut is likewise prevented by this modified hot water treatment employed for the loose smut.

TABLE III.— TREATMENT FOR LOOSE SMUT OF WHEAT, 1896-7.

| Plot. | Variety. | Source and condition of seed. | Treatment of seed. | Per cent. smutted. | | Yield per acre. | | Decrease from untreated. |
|---|---|---|---|---|---|---|---|---|
| | | | | Loose smut. | Stinking smut. | Straw, pounds. | Grain, bushels. | |
| 17 | Hicks .... | Treated plots of '95-6, clean ... | Untreated ..... | 0.9 | 0.0 | 1470. | 23. | ... |
| 18 | Hickman | Untreated '96, smutted ..... | " .. | 0.45 | 0.0 | 1665. | 22.25 | .... |
| 19 | " | Untreated '96, smutted ..... | Hot water 5 m. after soaking and standing . | 0.0 | 0.0 | 1620. | 20.5 | 1.7 |
| 20 | Hicks .... | Untreated '96, smutted ..... | Untreated .... | 0.9 | 2.0 | 1815. | 21.25 | .... |
| 21 | " .... | Untreated '96, smutted ..... | Hot water after soaking and standing ..... | 0.0 | 2 hds | 1695. | 20.75 | 0.5 |

All sown in moist, well prepared soil, September 26, 1896. Untreated seed at rate of 5 pecks per acre; treated seed about 1½ times as much.

## EXPERIMENTS WITH STINKING SMUT ON WHEAT.

This Station has made extended experiments along this line, part of which have already been published by the Agriculturalist, in earlier bulletins. In 1893, much stinking smut having appeared in the various varieties of wheat grown at the Station, all of the seed sown was treated by the blue-stone method and the smut was successfully prevented. Plot experiments in seed treatment have been continued for three years, beginning in 1895. For the first year's work, seed was secured from Mr. E. A. Manges, from a smutted crop, in which thirty-seven per cent had been found to be smutted. Some variation in the hot water treatment, as well as a small trial of soaking in Potassium Sulfid solution, the same as that used in oats, was tried this year. Seed grain from the crop of 1894 and 1895, was employed. Another interesting question, as to the possible infection of seed by sowing after smutted grain in the drill, was also investigated. See plots 5 and 6. The efficiency of the hot water treatment, at a temperature of 132-3° F. is well brought out in this, as in the experiments of the succeeding year. The results are shown in Tables IV and V.

TABLE IV.—EFFECT OF SEED TREATMENT UPON STINKING SMUT OF WHEAT, 1895–6.

| Plot. | Variety. | Source and condition of seed. | Treatment. | Per cent. smutted. | Yield per acre. |
|---|---|---|---|---|---|
| | | | | | *Bush.* |
| 1 | Poole | Seed of '94, E. A. Manges, smutted | Untreated | 13.9 | 4.62 |
| 2 | " | Seed of '94, E. A. Manges, smutted | Hot water, 131°, 15 m., not cooled, seed skimmed | 1.0 | 6.37 |
| 3 | " | Seed of '95, E. A. Manges, 37% smut | Untreated | 14.5 | 5. |
| 4 | " | Seed of '95, E. A. Manges, 37% smut | Hot water, 131°, 15 m., not cooled | .21 | 5.5 |
| 5 | " | O. A. E. S., '95, clean sown after smutty in drill | Untreated | 0.0 | 10.75 |
| 6 | " | As No. 5, sown clean | Hot water, 131°, 15 m., not cooled | 0.0 | 6. |
| 7 | " | Seed of '95, E. A. Manges, 37% smut | Untreated | 10.78 | 3.5 |
| 8 | " | Seed of '95, E. A. Manges, 37% smut | Hot water, 131°, 15 m., cooled | .18 | 2.75 |
| 9 | " | Seed of '95, E. A. Manges, 37% smut | Untreated | 16.3 | 3.12 |
| 10 | " | Seed of '95, E. A. Manges, 37% smut | Hot water, 132–3°, 10 m., cooled, sown wet | 0.0 | 2.5 |
| 11 | " | Seed of '95, E. A. Manges, 37% smut | Untreated | 11.35 | 4 |
| 12 | " | Seed of '95, E. A. Manges, 37% smut | Potas. sulfid, ¾%, 19 hrs., dried in sun | 7.81 | 2.25 |
| 13 | " | Seed of '95, E. A. Manges, 37% smut | Untreated | 10.08 | 3.75 |
| 14 | " | Seed of '95, E. A. Manges, 37% smut | Copper sulfate, 10 m. and 10 m., limed | 0.0 | 2.12 |
| 15 | " | Seed of '95, E. A. Manges, 37% smut | Untreated | 9.09 | 4.25 |
| 16 | " | Seed of '95, E. A. Manges, 37% smut | Hot water, 131°, 15 m., not cooled | .57 | 4. |
| 17 | " | Seed of '95, E. A. Manges, 37% smut | Untreated | 15.6 | 3.37 |
| 18 | " | Seed of '95, E. A. Manges, 37% smut | Hot water, 132–3°, 10 m., not cooled. | 0.0 | 5.75 |

SUMMARY:

| | *Per cent. smutted.* |
|---|---|
| Seed of 1894, untreated | 13.9 |
| " " 1895, average, untreated | 12.5 |
| " " 1895, hot water, 133°, 10 m | 0.0 |
| " " 1895, average, hot water 131°, 15 m | 0.32 |
| " " 1895, " copper sulfate | 0.0 |

TABLE V.—TREATMENT FOR PREVENTION OF STINKING SMUT, 1896–7.

| Plot. | Variety. | Source and condition of seed. | Treatment. | Per cent. smutted. | Yield per acre. Straw, pounds. | Yield per acre. Grain, bushels. | Increase over untreated, bushels. |
|---|---|---|---|---|---|---|---|
| 10 | Poole | Untreated plots of '95–6, 10—14% smut | Hot water, 132–3° F., 10 m | 0.006 [3 hds.] | 2500 | 33.3 | 5.0 |
| 11 | " | Untreated plots of '95–6, 10—14% smut | Untreated | 16.9 | 2360 | 28.3 | .... |
| 12 | " | Untreated plots of '95–6, 10—14% smut | Copper sulfate (4 lbs. to 10 gal.), 10 m. and 10 m. limed | 0.0018 [1 head] | 2260 | 29.7 | 2.9 |
| 13 | " | Untreated plots of '95–6, 10—14% smut | Untreated | 11.7 | 2500 | 27.3 | .... |
| 14 | " | Untreated plots of '95–6, 10—14% smut | Hot water, 131°, 15m., sown wet | 0.12 [6 hds.] | 2320 | 29. | 1.7 |
| 15 | " | Untreated plots of '95–6, 10—14% smut | Untreated (near tree) | 8.4 | 1980 | 16.8 | .... |
| 16 | " | Untreated plots of '95–6, 10—14% smut | Hot water, 132–3° F., 10 m | 0.004 [2 hds.] | 2380 | 32. | 4.7 |

The yields of grain for 1896 were so small that no inference as to the effect of treatment upon the yield of grain could be made. Those of 1897, on the other hand, are much more satisfactory, and relatively more favorable to the hot water treatment recommended for the prevention of stinking smut. With respect to the prevention of this form of smut these results are conclusive.

It will be observed that untreated seed, containing thirty-seven per cent. of smut, gave in 1895-6 an average of 12.5 per cent. of smutted heads, while the seed from this crop sown again in '96-7 yielded 12.4 per

cent. of stinking smut. It is also to be pointed out that treated seed yielding no smut promises immunity from the disease for more than one season, if the crop is handled without smut infection. The variety experiments, continued since 1893 without the reappearance of any stinking smut, bring this point out very clearly. Untreated seed, of these same varieties sown in small plots, but separately gathered and threshed, have shown a constantly increasing amount of stinking smut, in some cases this season reaching forty to seventy-five per cent. of the whole. It is clear that farmers cannot continue to sow smut infected seed when so small an expense as that involved in seed treatment will usually rid the seed grain, as well as the farm, of this offensive grain parasite. Either the hot water treatment, for ten minutes, at 132-3° F., or the copper sulfate (blue-stone treatment) in a solution made from two pounds of sulfate to ten gallons of water, seed immersed ten minutes, gives complete prevention of stinking smut. The choice of methods will be governed by other circumstances than relative efficiency. These circumstances will depend upon the situation of the wheat grower. The corrosive sublimate, and formalin treatment for stinking smut, successfully employed by Bolley[16] have not been employed in these experiments except in one trial with formalin. In this series, for some reason, no sum was found in any plots and no results were obtained.

### POSSIBLE EFFECT OF SEED TREATMENT UPON SMUT-FREE GRAIN.

The influence of seed treatment upon the yield of grain, so marked in the work with oat smut,[17] suggested an inquiry into the effects of treatment upon smut-free seed wheat. Such an experiment was tried in 1895, but entirely lost by winter killing and by rains following harvest. Table VI gives the issue of an experiment with Valley wheat in 1896-7. No apparent increase was obtained on the treated plots, as shown in the summary.

[17] Bulletin 64, Ohio Experiment Station, 136.
[16] Bulletin 27, North Dakota Experiment Station.

TABLE VI.— EFFECT OF SEED TREATMENT UPON YIELD, 1896-7.

| Plot. | Variety. | Treatment | Rate of seed per acre. | Yield per acre. | |
|---|---|---|---|---|---|
| | | | | Straw, pounds. | Grain, bushels. |
| | | | *Bush.* | | |
| 1 | Valley. | Hot water, 132-3°, 10 m | 1.6 | 2360 | 25.7 |
| 2 | " . | Untreated | 1.25 | 2720 | 29.5 |
| 3 | " . | Copper sulfate, 10 m. and 10m. limed | 1.54 | 1900 | 22.7 |
| 4 | " . | Untreated | 1.25 | 2060 | 24.7 |
| 5 | " . | Potas. sulphid, sprinkling ¾% sol., 2 hrs | 1.37 | 2360 | 26.7 |
| 6 | " . | Untreated | 1.25 | 2420 | 27.7 |
| 7 | " . | Hot water, 132-3°, 10m | 1.6 | 2120 | 25.7 |
| 8 | " . | Untreated | 1.25 | 1700 | 22.3 |
| 9 | " . | Copper sulfate, 10 m. and 10 m. limed | 1.54 | 2320 | 25.3 |
| | | SUMMARY. | | | |
| | | Untreated, average | | ..... | 26.0 |
| | | Hot water, 133°, 10 m., average | | ..... | 25.7 |
| | | Copper sulfate, average | | ..... | 26.0 |
| | | Potas. sulfid, one plot only | | ..... | 26.7 |

## FURTHER EXPERIMENTS IN THE PREVENTION OF OAT SMUT.

The results of the oat smut experiments made at this Station in 1895 were published in Bulletin 64. During the last three years the experiments have been continued and extended, so that we are now able to announce the entire success of a shortened, and therefore less expensive, hot water treatment for oat smut; the failure of the proprietary "Ceres Pulver" to show any superiority over ordinary potassium sulfid, and the insufficiency of either of these substances, applied in solutions by sprinkling heaps of grain, to prevent oat smut to a satisfactory degree.

The first year's trials (1896) were made with a view to testing the further efficacy of the hot water treatment and the relative efficiency of that treatment compared with Ceres Pulver and potassium sulfid. The same comparisons, with shortening the time of immersion in hot water

TABLE VII.— OAT SMUT EXPERIMENTS, 1896.

SERIES A.

| Plot. | Variety. | Source and condition of seed. | Treatment. | Per cent. smutted. | Yield per acre. | | Increase over untreated plots, bushels. |
|---|---|---|---|---|---|---|---|
| | | | | | Straw, pounds. | Grain, bushels. | |
| 1 | Seizure | Untreated, '95, smut 8% | Hot water, 132–3°, 15m. | .03 | 1160 | 33.13 | 6.57 |
| 2 | " | Untreated, '95, smut 8% | " " 132–3°, 10m. | .14 | 1350 | 35.94 | 9.38 |
| 3 | " | Untreated, '95, smut 8% | Untreated | 12.11 | 1450 | 26.56 | ..... |
| 4 | " | Untreated, '95, smut 8% | Potas sulfid, ¾% sol., 24 hrs. soaking | .08 | 1490 | 32.19 | 6.06 |
| 5 | " | Untreated, '95, smut 8% | Ceres pulver, 1 lb. to 16 gal. water, sprinkling | 1.22 | 1180 | 33.13 | 7.40 |
| 6 | " | Untreated, '95, smut 8% | Potas sulfid, 1 lb. to 16 gal. water, sprinkling | 1.08 | 1165 | 33.59 | 8.26 |
| 7 | " | Untreated, '95, smut 8% | Hot water, 132–3°, 15m. | .16 | 1365 | 36.72 | 11.79 |
| 8 | " | Untreated, '95, smut 8% | Untreated | 13.5 | 1215 | 24.53 | ..... |
| 9 | " | Untreated, '95, smut 8% | Hot water, 132–3°, 10m. | .03 | 1610 | 37.19 | 11.41 |
| 10 | " | Untreated, '95, smut 8% | Potas sulfid, ¾% sol., 24 hrs. soaking | .21 | 1290 | 30.94 | 3.91 |
| 11 | " | Untreated, '95, smut 8% | Ceres pulver, 1 lb. to 16 gal. water, sprinkling | .99 | 1780 | 37.50 | 9.22 |
| 12 | " | Untreated, '95, smut 8% | Untreated | 16.5 | 1755 | 29.53 | ..... |
| 13 | " | Untreated, '95, smut 8% | Potas sulfid, 1 lb. to 16 gal. water, sprinkling | 2.66 | 1550 | 33.44 | 3.91 |
| | | | SUMMARY OF SERIES A. | | | | |
| | | | Hot water, 132–3°, 15 m. average | 0.10 | ..... | 34.93 | 9.38 |
| | | | Hot water, 132–3°, 10 m. average | 0.09 | ..... | 36.56 | 10.4 |
| | | | Potas. sulfid, soaking, average | 0.15 | ..... | 31.56 | 4.99 |
| | | | Potas. sulfid, sprinkling, average | 1.87 | ..... | 33.51 | 6.08 |
| | | | Ceres pulver, sprinkling, average | 1.11 | ..... | 35.31 | 8.31 |
| | | | Untreated, average | 14.04 | ..... | 26.87 | ..... |

TABLE VII.— OAT SMUT EXPERIMENTS, 1896.— Concluded.

SERIES B.

| Plot. | Variety. | Source and condition of seed. | Treatment. | Per cent. smutted. | Yield per acre. | | Increase over untreated plots, bushels. |
|---|---|---|---|---|---|---|---|
| | | | | | Straw, pounds. | Grain, bushels. | |
| 14 | Seizure | Treated, '95, .11 % smut ..... | Untreated ..... | 4.15 | 1295 | 32.34 | ..... |
| 15 | " | Treated, '95, .11 % smut ..... | Hot water, 132-3°, 15 m. sown wet ..... | .21 | 1360 | 31.25 | —.31 |
| 16 | " | Treated, '95, .11 % smut ..... | Potas. sulfid, 24 hrs. soaking ..... | .11 | 1360 | 34.38 | 3.60 |
| 17 | " | Treated, '95, .11 % smut ..... | Untreated ..... | 3.05 | 1230 | 33.44 | ..... |
| 18 | " | Treated, '95, .11 % smut ..... | Hot water, 132-3°, 15 m. | .03 | 1355 | 35.78 | 6.56 |
| 19 | " | Treated, '95, .11 % smut ..... | Potas. sulfid, 24 hrs. soaking ..... | .04 | 1395 | 31.41 | 2.97 |
| 20 | " | Treated, '95, .11 % smut ..... | Untreated ..... | 3.6 | 1115 | 27.66 | ..... |

to reduce cost of treatment, received attention in 1897; while only the further test of different periods of immersion at different temperatures seemed necessary in 1898. Formalin, or Form-aldehyde, was tried in 1896 in a limited way, with the same interesting results. This fungicide is especially noticeable in its effects upon seed germination.

In the field experiments for which yields are stated the plots were 1-10 or 1-20 acre each; while in the small plots, tabulated without yields, the areas were a few square feet only, usually about five feet square.

TABLE VIII.—OAT SMUT EXPERIMENTS IN 1896—SMALL PLOTS.

| Plot. | Variety. | Condition of seed. | Treatment. | Per cent. of smut. |
|---|---|---|---|---|
| 1 | Lincoln | Seed with 58.8% smut | Ceres pulver, per Jensen, treated Mch. 23 | 8.2 |
| 2 | " | Seed with 58.8% smut | Potas. sulfid, sprinkling, treated Mch. 23 | 8.37 |
| 3 | " | Seed with 58.8% smut | Untreated | 27.84 |
| 4 | " | Seed with 58.8% smut | Ceres pulver, per Jensen, sown wet | 13.21 |
| 5 | " | Seed with 58.8% smut | Potas. sulfid, sprinkling as above, sown wet | 12.24 |
| 6 | " | Seed with 58.8% smut | Hot water, 132–3°, 15 m | .83 |
| 7 | " | Seed with 58.8% smut | Potas. sulfid, ¾% sol., 24 hrs., soaking | .50 |
| 8 | " | Seed with 58.8% smut | Untreated | 20.86 |
| 9 | " | Seed with 58.8% smut | Ceres pulver, per Jensen, treated Mch. 23 | 11 31 |
| 10 | " | Seed with 58.8% smut | Potas. sulfid, sprinkling, treated Mch. 23 | 8.12 |
| 11 | " | Seed with 58.8% smut | Ceres pulver, per Jensen, sown wet. | 13.64 |
| 12 | " | Seed with 58.8% smut | Potas. sulfid, sprinkling, sown wet | 11.78 |
| 13 | " | Seed with 58.8% smut | Hot water, 132–3°, 15 m | .67 |
| 14 | " | Seed with 58.8% smut | Hot water, 132–3°, 10 m | .43 |
| 15 | " | Seed with 58.8% smut | Untreated | 25.09 |
| 16 | " | Seed with 58.8% smut | Potas. sulfid, ¾% sol., 24 hrs., soaking | .75 |
| 17 | " | Seed with 58.8% smut | Hot water, 132–3°, 10m | .02 |
| | | | SUMMARY OF LINCOLN. | |
| | | | Hot water, 132–3°, 15 m., average | 0.75 |
| | | | Hot water, 132–3°, 10 m., average | 0.23 |
| | | | Potas. sulfid, sprinkling, treated Mch. 23 | 8.25 |
| | | | April 29 | 12.01 |
| | | | Ceres pulver sprinkling, treated Mch. 23 | 9.76 |
| | | | April 29 | 13.43 |
| | | | Potas. sulfid, soaking | 0.63 |
| | | | Untreated | 24.6 |
| 18 | " | Treated plot of '95, 2.2% smut | " | 16.42 |
| 19 | " | Treated plot of '95, 2.2% smut | " | 22.11 |

TABLE VIII.—OAT SMUT EXPERIMENTS IN 1896—SMALL PLOTS.—Concluded.

| Plot. | Variety. | Source and condition of seed. | Treatment. | Per cent. of smut. |
|---|---|---|---|---|
| 20 | Black Prolific. | Untreated plot of '95, 31.05% smut | Untreated | 13.62 |
| 21 | " | Treated plot of '95, .21% smut | " | 14.13 |
| 22 | " | Untreated plot of '95, 31.05% smut | " | 21.82 |
| 23 | " | Treated plot of '95, .21% smut | " | 11.70 |
| 24 | Seizure | Unsmutted, '95 | " | 8.28 |
| 25 | " | Heads smutted, '95, 12.08% smut | " | 2.75 |
| 26 | " | Heads smutted, '95, 8.87% smut | " | 7.05 |
| 27 | " | Untreated plots of '95, 10.4% smut | " | 10.81 |
| 28 | " | F. M. Selby, Bartlett, O | " | 13.29 |
| 29 | " | Treated plot of '95, .45% smut | " | 5.38 |
| 30 | " | Treated plot of '95, .11% smut | " | 3.08 |
| 31 | " | Unsmutted, '95 | " | 4.97 |
| 32 | " | Heads smutted, '95, 12.08% smut, '95 | " | 3.78 |
| 33 | " | Heads smutted, '95, 8.87% smut | " | 3.70 |
| 34 | " | Untreated plots of '95, 10.4% smut | " | 13.36 |
| 35 | " | F. M. Selby | " | 9.23 |
| 36 | " | Treated plot of '95, .45% smut | " | 6.95 |

TABLE VIII.—OAT SMUT EXPERIMENTS IN 1896—SMALL PLOTS, SEED TREATED AND AFTERWARDS SMUTTED.

| Plot. | Variety. | Treatment of seed. | Per cent. of smut. |
|---|---|---|---|
| 37 | Lincoln. | Ceres pulver, ¾ oz. per gal., 7 hrs., sown wet, smutted while moist by sifting smut from Lincoln | 6.11 |
| 38 | " | Potas. sulfid, ¾ oz. per gal., 7 hrs., sown wet, smutted while moist by sifting smut from Lincoln | 6.56 |
| 39 | " | Hot water, 132–3°, 15 m., smutted while moist from "open" smut of Race Horse | .07 |
| 40 | " | Hot water, 132–3°, 10 m., smutted while moist from Lincoln and "open" smut of Race Horse | 4.35 |
| 41 | " | Potas. sulfid, ¾% sol., 24 hrs., smutted dry with "open" smut from Race Horse | .57 |
| 42 | " | Hot water, 132–3°, 15 m., smutted while moist with "hidden" smut of Race Horse | 13.32 |
| 43 | " | Ceres pulver, ¾ oz. per gal., 7 hrs., kept moist for two days | 7.57 |
| 44 | " | Potas. sulfid, ¾ oz. per gal., 7 hrs., kept moist for two days | 8.53 |

It will be perceived from Table VI that there was little difference in 1896 between ten minutes and fifteen minutes immersion of the seed oats in hot water. Both gave the best smut prevention and the highest increase in yield. The potassium sulfid soaking method of Kellerman and Swingle stands next as to smut prevention, but loses in yield. There is very slight difference in the results of the Ceres Pulver and potassium sulfid, both applied in like strength and solution and in the same manner. The Ceres Pulver here used was purchased by the Experiment Station through its agent in Germany immediately after the publication of the articles concerning it in the German periodicals. It came in the ordinary sized bottles with the label of the Deutsche Ceres, Kopenhagen. The potassium sulfid employed was such as is ordinarily used in the chemical laboratory of the Station, having been purchased upon the market. Both were preserved in stoppered bottles and there is no evidence of any serious deterioration in either. The inadequacy of the strength of solution and method of application given in the directions upon the bottles containing Ceres Pulver, when this treatment is applied to seed grain containing a very high percentage of smut, is brought out even more clearly in Table VIII. In these small plots, seed of the Lincoln variety, from a plot containing 58.8 per cent. of smut in 1895, gives when untreated 24.6 per cent. of smut. Treatment by Ceres Pulver and potassium sulfid, made one month before sowing, reduces this amount to from 8 to 9 per cent. of smut. While from the seed freshly treated by either chemical, following the sprinkling method, the percentage of smut is reduced one-half, or less.

On the other hand the hot water methods of treatment bring this amount to one-fourth of one per cent, and three-fourths of one per cent. respectively. While there was no reason to think that the results as to smut prevention would differ greatly in different years, these experiments were continued with Ceres Pulver and potassium sulfid in 1897.

Several interesting points in connection with the question of time and manner of the smut infection of the seed oats is brought up by the further tabulations given in Table VIII. These show, clearly, the danger of smut infection from smut-free or nearly smut-free grain growing alongside smutted grain.

It will be seen that seed from the treated Lincoln of 1895 which contained in the plot but 2.2 per cent of smut gave 19.2 per cent. of smut in the crop while the seed from the untreated plot which grew alongside the former in 1895 gave but little more smut, namely 24.6 per cent. Clearly the lesson to be drawn from the various cases cited in the table is the necessity not only of treating the seed to prevent smut, but the separation of such smut-free grain from smutted grain in the field, in order to secure a crop which may be relied upon to remain free from smut.

For 1897 another variety, Wideawake seed was chosen for experimentation. This contained about 40 per cent. of smut in the crop. It was also sought to discover how much the efficiency of the hot water treatment might be impaired by raising the temperature and shortening the time to five minutes. The comparisons between Ceres Pulver and potassium sulfid solutions of various strengths were continued, as shown in the table:

TABLE IX.—OAT SMUT EXPERIMENTS IN 1897.

| Plot. | Variety. | Condition of seed. | Treatment. | Per cent. smutted. | Yield per acre. | | Net increase of yield over untreated, bushels. |
|---|---|---|---|---|---|---|---|
| | | | | | Straw, pounds. | Grain, bushels. | |
| 1 | Wideawake | Containing 40% smut | Hot water, 133°, 10m ... | .5 | 1260 | 37.5 | 5.7 |
| 2 | " | Containing 40% smut | Untreated ..... | 26. | 1320 | 31.8 | ..... |
| 3 | " | Containing 40% smut | Potas. sulfid, 1 lb.,–15.5 gal. .8% solution, sprinkling ..... | 10. | 1090 | 34.6 | 2.2 |
| 4 | " | Containing 40% smut | Ceres pulver, .8% solution, sprinkling..... | 7.7 | 1280 | 38.3 | 5.3 |
| 5 | " | Containing 40% smut | Potas. sulfid, 1½ lb.,–15 gal. 1.2% solution, sprinkling ..... | 7.2 | 970 | 35.3 | 1.77 |
| 6 | " | Containing 40% smut | Untreated ..... | 25.8 | 1100 | 34.3 | ..... |
| 7 | " | Containing 40% smut | Potas. sulfid, 2 lbs.,–15 gal. 1.6% solution, sprinkling ..... | 7.7 | 1160 | 45. | 11.4 |
| 8 | " | Containing 40% smut | Hot water, 136°, 5m .... | .1. | 1860 | 48.1 | 14.7 |
| 9 | " | Containing 40% smut | Hot water, 140°, 5m .... | .5 | 1090 | 37.8 | 4.0 |
| 10 | " | Containing 40% smut | Untreated ..... | 26.9 | 1260 | 32.5 | ..... |
| 11 | " | Containing 40% smut | Hot water, 144°, 5m .... | .6 | 1090 | 37.5 | 4.4 |
| 12 | " | Containing 40% smut | " 133°, 10m ... | .5 | 1160 | 32.5 | —1.2 |
| 13 | " | Containing 40% smut | Potas. sulfid, .8% solution, sprinkling.... | 14. | 1200 | 35. | +.6 |
| 14 | " | Containing 40% smut | Untreated ..... | 22.4 | 1220 | 35. | ..... |
| 15 | " | Containing 40% smut | Ceres pulver, .8% solution, sprinkling ..... | 10.5 | 1470 | 38.4 | 4.2 |
| 16 | " | Containing 40% smut | Potas. sulfid, 1.2% solution, sprinkling .... | 9.2 | 1760 | 48.1 | 14.7 |

TABLE IX.— OAT SMUT EXPERIMENTS IN 1897 — Concluded.

| Plot. | Variety. | Condition of seed. | Treatment. | Per cent. smutted. | Yield per acre. | | Net increase of yield over untreated, bushels. |
|---|---|---|---|---|---|---|---|
| | | | | | Straw, pounds. | Grain, bushels. | |
| 17 | Wideawake | Containing 40% smut | Potas. sulfid, 1.6% solution, sprinkling..... | 7.4 | 1510 | 41.5 | 8.9 |
| 18 | " | Containing 40% smut | Untreated ..... | 26.8 | 1180 | 31.8 | ..... |
| 19 | " | Containing 40% smut | Hot water, 136°, 5m .... | 1.8 | 1090 | 36.5 | 6.4 |
| 20 | " | Containing 40% smut | " 140°, 5m .... | .7 | 960 | 33.7 | 5.44 |
| 21 | " | Containing 40% smut | " 144°, 5m .... | .6 | 920 | 31.8 | 5 3 |
| 22 | " | Containing 40% smut | Untreated ..... .. . | 28.1 | 930 | 24.7 | ..... |
| | | | SUMMARY WIDEAWAKE RESULTS. | | | | |
| | | | Hot water, 133°, 10 m., average ..... | 0.5 | ..... | 35.0 | 3.45 |
| | | | Hot water, 136°, 5 m., average ..... | 1.4 | ..... | 42.3 | 10.55 |
| | | | Hot water, 140°, 5 m., average ..... | 0.6 | ..... | 35.75 | 4.7 |
| | | | Hot water, 144°, 5 m., average ..... | 0.6 | ..... | 34.06 | 4.85 |
| | | | Ceres pulver, 0.8% solution as per directions | 7.2 | ..... | 38.35 | 4.75 |
| | | | Potas. sulfid, 0.8% solution as Ceres pulver . | 12.0 | ..... | 34.8 | 0.08 |
| | | | Potas. sulfid, 1.2% solution as Ceres pulver . | 8.2 | ..... | 41.65 | 8.2 |
| | | | Potas. sulfid, 1.6% solution as Ceres pulver . | 7.55 | ..... | 43.25 | 10.15 |
| | | | Untreated, of same seed as all above, average . | 26.00 | ..... | 31.7 | ..... |
| 23 | Seizure ... | 12% smutted, ('96) . | Potas. sulfid, 8 gr.–1 l. Approx. 1 lb.–15 gal.. | .4 | 2440 | 52.5 | —4.37 |
| 24 | " ... | 12% smutted, ('96) . | Untreated ..... | 2.2 | 2880 | 56.87 | ..... |
| 25 | " ... | 12% smutted, ('96) . | Ceres pulver, 1 lb.–15 gal. | .5 | 2140 | 53.75 | —2.24 |
| 26 | " ... | 12% smutted, ('96) . | Hot water, 133°, 10m ... | 1.5 | 2080 | 55. | — .31 |
| 27 | " ... | 12% smutted, ('96) . | Potas. sulfid, 1½ lb.–15 gal | .7 | 1780 | 48.75 | —5.78 |
| 28 | " ... | 12% smutted, ('96) . | Untreated ..... | 1.5 | 2000 | 53.75 | ... .. |
| 29 | " ... | 12% smutted, ('96) . | Hot water, 138°, 5m .... | .1 | 2280 | 56.87 | 3.12 |

From the summary given it will be perceived that Ceres Pulver and potassium sulfid treatments were no more efficient than in 1896, while shorter time and higher temperature, between 140° and 144° F., five minutes, gave practically the same results as the standard treatment of 133°, ten minutes. The yields are not without anomalies that are fully stated in the table.

In the experiments for 1898 the hot water treatment alone was used and this subject of higher temperature and reduced time received further elucidation. Unlike the results of 1897, the treatment at 136° for five minutes gave a lower percentage of smut than some others.

TABLE X.— OAT SMUT EXPERIMENTS IN 1897, STRONGSVILLE, OHIO.

| Plot. | Variety. | Treatment. | Per cent. smut. | Yield per acre. | | Increase over untreated, bushels. |
|---|---|---|---|---|---|---|
| | | | | Straw, pounds. | Grain, bushels. | |
| 1 | Wideawake, with 40% smut as in Table IX | Untreated | 8. | 325 | 10.47 | ..... |
| 2 | Wideawake, with 40% smut as in Table IX | Ceres pulver, .8% solution, sprinkling | 4. | 630 | 14.69 | 2.74 |
| 3 | Wideawake, with 40% smut as in Table IX | Potas. sulfid, .8% sol., sprinkling | 3.3 | 590 | 16.56 | 3.13 |
| 4 | Wideawake, with 40% smut as in Table IX | Hot water, 133°, 10 m | .1 | 595 | 17.03 | 2.12 |
| 5 | Wideawake, with 40% smut as in Table IX | Untreated | 8.9 | 635 | 16.41 | ..... |
| 6 | Wideawake, with 40% smut as in Table IX | Potas. sulfid, 2 lb. 15 gal., 1.6% sol., sprinkling | 3.2 | 595 | 17.66 | 1.93 |
| 7 | Wideawake, with 40% smut as in Table IX | Ceres pulver, .8% sol., sprinkling | 1.5 | 545 | 17.34 | 2.27 |
| 8 | Wideawake, with 40% smut as in Table IX | Potas. sulfid, .8% sol. | 1.4 | 600 | 17.50 | 3.09 |
| 9 | Wideawake, with 40% smut as in Table IX | Untreated | 9. | 640 | 13.75 | ..... |
| 10 | Wideawake, with 40% smut as in Table IX | Hot water, 133°, 10 m | .6 | 465 | 15.47 | 1.93 |
| 11 | Wideawake, with 40% smut as in Table IX | Potas. sulfid, 2 lbs. to 15 gal. | 1.7 | 570 | 15.62 | 2.27 |
| 12 | Wideawake, with 40% smut as in Table IX | Hot water, 144°, 5 m | ..... | 465 | 14.87 | 1.61 |
| 13 | Wideawake, with 40% smut as in Table IX | Untreated | 6.3 | 585 | 12.97 | ..... |
| 14 | Wideawake, with 40% smut as in Table IX | Formalin, ¼% sol., 2 hrs | .7 | 540 | 15.00 | 2.03 |
| 15 | Wideawake, with 40% smut as in Table IX | Hot water, 144°, 5 m | .1 | 480 | 14.38 | 1.41 |

TABLE XI.— OAT SMUT EXPERIMENTS IN 1897 — SMALL PLOTS.

| Plot. | Variety. | Condition of seed. | Treatment. | Per cent. of smut. |
|---|---|---|---|---|
| 30 | Wideawake | Containing 40% of smut. | Untreated | 16 |
| 31 | " | " " " | Hot water, 138°, 5 m | .4 |
| 32 | " | " " " | " 142°, 5 m | .1 |
| 33 | " | " " " | " 146°, 5 m | 1. |
| 34 | " | " " " | Untreated | 15.4 |
| 35 | " | " " " | Hot water, 148°, 5 m | .5 |
| 36 | " | " " " | " 150°, 5 m | 1.4 |
| 37 | " | " " " | " 133°, 10 m | 0.0 |
| 38 | " | " " " | Untreated | 16.8 |
| 39 | " | " " " | Ceres pulver, per Jensen, .8% sol., sprinkling | 6.6 |
| 40 | " | " " " | Potas. sulfid, 1 lb.–15½ gal., .8% sol., sprinkling | 6.9 |
| 41 | " | " " " | Ceres pulver, 1.6% sol., sprinkling | 10.1 |
| 42 | " | " " " | Untreated | 19.7 |
| 43 | " | " " " | Potas. sulfid, 1.6% sol., sprinkling | 7. |
| 44 | " | " " " | Potas. sulfid, 2% sol., sprinkling | 15.0 |
| 45 | " | " " " | " 3% " " | 13.5 |
| 46 | " | " " " | Untreated | 14.5 |
| 47 | " | " " " | Potas. sulfid, 6% sol., sprinkling | 6.0 |
| 48 | " | " " " | " .8% " " | 9.6 |
| 49 | " | " " " | " 1.6% " | 4.6 |
| 50 | " | " " " | Untreated | 18.6 |
| 51 | " | " " " | Formalin, ¼% sol., 2 hrs, dried | .1 |
| 52 | " | " " " | Formalin, ¼% sol. ½ hr., 2 hrs. in bag, dried | 1. |
| 53 | " | " " " | Formalin, ¼% sol., sprinkling, 1 gal. to bu., dried after 3 hrs. | 0.0 |
| 54 | " | " " " | Untreated | 24.6 |
| 55 | " | " " " | Hot water, 138°, 5 m | .8 |
| 56 | " | " " " | " 142°, 5 m | .9 |
| 57 | " | " " " | " 146°, 5 m | 1. |
| 58 | " | " " " | Untreated | 24.1 |
| 59 | " | " " " | Hot water, 148°, 5 m | 1.6 |
| 60 | " | " " " | " 150°, 5 m | .7 |
| 61 | " | " " " | " 133°, 10 m | .2 |
| 62 | " | " " " | Untreated | 19.5 |
| 63 | " | " " " | Ceres pulver, .8% sol | 7.9 |
| 64 | " | " " " | Potas. sulfid, .8% sol | 9.8 |
| 65 | " | " " " | Ceres pulver, 1.6% sol | 9.8 |
| 66 | " | " " " | Untreated | 28.2 |
| 67 | " | " " " | Potas. sulfid, 1.6% sol | 11.7 |
| 68 | " | " " " | " 2% " | 13.7 |
| 69 | " | " " " | " 3% " | 12. |
| 70 | " | " " " | Untreated | 20.4 |
| 71 | " | " " " | Potas. sulfid, 6% sol | 7. |
| 72 | " | " " " | " .8% " | 5.9 |
| 73 | " | " " " | " 1.6% " | 3. |
| 74 | " | " " " | Untreated | 12.1 |
| 75 | " | " " " | Formalin, ¼% sol. 2 hrs., dried | .6 |

TABLE XI.—OAT SMUT EXPERIMENTS IN 1897—SMALL PLOTS.—Concluded.

| Plots. | Variety. | Condition of seed. | Treatment. | Per cent. of smut. |
|---|---|---|---|---|
| 76 | Wideawake | Containing 40% of smut. | Formalin, ¼% sol. ½ hr., 2 hrs. in wet bag, dried | .9 |
| 77 | " | " " " | Formalin, ¼% sol. sprinkling, 1 gal. per bu., dried after 3 hrs. | 0.0 |
| 78 | " | " " " | Untreated | 7. |
| 79 | " | " " " | Formalin, ½% sol. 30 m., dried | 0.0 |
| 80 | " | " " " | " ½% sol. 1 hr | .3 |
| 81 | " | " " " | " ¼% sol. 30 m., 1 hr. in bag | .2 |
| 82 | " | " " " | Untreated | 15.6 |
| 83 | " | " " " | Formalin, ½% sol. 30 m., dried | 0.0 |
| 84 | " | " " " | " ½% sol. 1 hr., dried | .1 |
| 85 | " | " " " | " ¼% sol. 30 m., 1 hr. in bag | 5.4 |

TABLE XII.—OAT SMUT EXPERIMENTS FOR 1898.

| Plot. | Variety. | Condition of seed. | Treatment. | Per cent. smutted. | Yield per acre. Straw pounds. | Yield per acre. Grain bushels. | Increase per acre over untreated bushels. |
|---|---|---|---|---|---|---|---|
| 1 | Wideawake | Containing 26% smut | Untreated | 13.33 | 1375 | 32.03 | ..... |
| 2 | " | Containing 26% smut | Water, 133°, 10 m | .22 | 1165 | 30.78 | 0.39 |
| 3 | " | Containing 26% smut | " 136°, 5 m | 0.0 | 1335 | 31.71 | 1.32 |
| 4 | " | Containing 26% smut | Untreated | 11.11 | 1270 | 28.75 | ..... |
| 5 | " | Containing 26% smut | Water, 140°, 5 m | .62 | 1135 | 32.65 | 5.47 |
| 6 | " | Containing 26% smut | " 144°, 5 m | .07 | 1105 | 27.96 | — .78 |
| 7 | " | Containing 26% smut | Untreated | 13.83 | 1300 | 25.62 | ..... |
| 8 | " | Containing 26% smut | Water, 133°, 10 m | .26 | 1155 | 26.40 | .78 |
| 9 | " | Containing 26% smut | " 136°, 5 m | .11 | 845 | 26.09 | 1.25 |
| 10 | " | Containing 26% smut | Untreated | 9.93 | 1100 | 24.06 | ..... |
| 11 | " | Containing 26% smut | Water, 140°, 5 m | .47 | 1390 | 26 25 | 1.88 |
| 12 | " | Containing 26% smut | " 144°, 5 m | .08 | 1290 | 25.93 | 1.56 |
| 13 | " | Containing 26% smut | Untreated | 10.17 | 1160 | 24.68 | ..... |

In the experiments set forth in Table X, valuable assistance was rendered by Mr. Edward Mohn of the Northeastern Sub-station. In the various experiments assistance of great value was rendered by Messrs. John C. Britton, Bertram H. Thorne and Jos. W. T. Duvel.

## CONCLUSIONS.

As shown in the foregoing pages, the diseases of wheat in Ohio are loose smut, stinking smut, rust and scab; the greater losses being caused by the first named diseases. The loose and stinking smuts of wheat alone cause an annual loss of $400,000 to $500,000 in Ohio. The losses due to oat smut are equal to, or even greater than those just stated. These losses are entirely preventable and need not be sustained. The losses caused by rust, scab, etc., are at times considerable but in the light of present knowledge are not so readily preventable as are those due to the smuts.

### TREATMENT RECOMMENDED FOR SMUT PREVENTION.

*For loose smut of wheat:*

Modified hot water treatment as shown on page 43: Soak the seed grain for four hours in cold water, let stand four hours more in the wet sacks, then immerse for 5 minutes in water at a temperature of 133° F.; spread at once on a smut-free surface to dry and sow. Use one-half more seed to replace that injured by the treatment.

*For stinking smut of wheat:*

In all the methods employed for stinking smut it is probably advisable to immerse grain first in cold water with stirring, and to skim off the smut balls which will in this manner rise to the top of the water. After this is completed either of the following treatments may be employed —

1. *Hot Water:* Immerse this skimmed seed contained in gunny bag, or suitable wire-mesh vessel for 10 minutes in hot water at a temperature of 133° F., then dry on smut-free surface, cooling quickly by thoroughly stirring, or cold water may be employed to cool the grain. Remember these temperatures are to be determined by a thermometer, longer immersion than 10 minutes at that temperature may injure the grain.

2. *Blue-Stone, Copper sulfate:* Make a solution at the rate of 2 pounds to 10 gallons of water (1 pound to 5 gallons), in this solution immerse the seed wheat, freed from the smut balls as before described, for 10 minutes. Allow to stand 10 minutes in sack to drain, then spread and dry with air slaked lime, shoveling over frequently. Or by sprinkling; use the above solution at rate of one gallon to one bushel of grain in heap. Apply by sprinkling can at intervals of 5 or 10 minutes; stir the whole so as to be uniformly wet; at the end say, of one hour, shovel over and dry with lime if desired.

3. *Formalin:* This may be used at the rate of 1 pound to 50 gallons of water and the seed treated by sprinkling or by immersion for 30 minutes.

FOR OAT SMUT.

1. *Hot Water:*

Immerse the seed oats, contained in a suitable open vessel, for 10 minutes at 133° F. or 7 minutes at 136° F. or 5 minutes at 140° or 142° F. Empty at once upon clean floor and dry by stirring.

2. *Formalin:*

Thoroughly saturate a pile of seed oats with formalin solution at the rate of 1 pound of formalin to 50 gallons of water (about 1 gallon of solution to a bushel of grain will be required) allow the grain to remain in a pile for two or more hours, then spread to dry. Or dip the seed oats in the formalin solution for 2 hours, then dry.

3. *Potassium Sulfid:*

Soak the seed oats for 24 hours in a ¾% solution of potassium sulfid (1½ pounds to 25 gallons of water); then spread on clean surface and stir frequently until dry.

The methods stated in several places wherein Ceres Pulver and ordinary potassium sulfid were employed by sprinkling the piles of grain have not been sufficiently successful to warrant their recommendation.

The cost of seed treatment of oats by the ordinary hot water method need not exceed 10 cents per bushel treated.

NOTE: That for convenience in the application of the hot water method it is ordinarily advisable to have two vessels; one in which the water is maintained at a temperature of 120 to 130° F., into which the grain is at first dipped to warm it, thus making it possible to maintain a more nearly uniform temperature in the heating vessel, and a second vessel in which the water should be maintained at the temperature desired. If possible to heat water by means of a steam jet or boiling water drawn directly from some large supply the single vessel will be sufficient, as the temperature can easily be maintained by turning the valve and admitting more steam, etc. The introduction of a mass of cold grain will cause a sharp fall of the temperature of the water. Open gunny bags, wire-mesh vessels, or open baskets provided with suitable cover may be advantageously used in the treatment of seed grain by this method. It is advisable, by plunging, twirling or otherwise stirring the contents of the vessel, to bring all of the grain to same temperature immediately after its introduction.

REMEMBER: That oats thoroughly freed from smut by seed treatment, or wheat thus cleaned of smut, if not grown near fields of smutted grain, may be kept free from these parasites for several years by a single treatment. The treatment does not require to be repeated each year if the precautions just indicated are taken.

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